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ABSTRACT

Reviewed ar 14 studies pertaining to teaching and learning the nature of science. A brief "digest" is prepared of each study, listing author/source, subjects, problem, instruments used, and findings. Conclusions supported by the findings of these studies are made regarding the inadequate levels of understanding of science teachers of the nature of science; the factors (length of teaching experience, quality or quantity of academic course work) that apparently have no influence on science teachers' understanding of the nature of science; and the factors (appropriately designed institutes, science courses, and science education courses) that have a positive influence on producing teacher and/or student growth in understanding the nature of science. Suggestions for research to provide more information on the teaching and learning of the nature of science include: (1) large-scale studies that increase possibilities for generalization; (2) studies dealing with science concepts taught in elementary school; (3) studies involving actual classroom instruction of teachers who score high on understanding of the nature of science; and (4) studies to determine what factors predispose teachers to use teaching strategies accurately conveying the nature of science. (Author/CS)

A REVIEW OF EMPIRICAL STUDIES PERTAINING TO THE "NATURE OF SCIENCE"*

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INTRODUCTION

The launching of Sputnik and the ensuing space race focused national attention on weaknesses in the science curriculum. One of the more significant weaknesses identified was the widespread failure of science programs to provide youth with a genuine understanding of "The Nature of Science." Widely used teaching methods and instructional materials tended to depict science as a static body of immutable facts and laws and, in the more extreme cases, as simply an array of dreary definitions to be learned. In short, the "nature of science" was not evident in the majority of the science programs. Science instruction did not convey science as a method; as an on-going, self-correcting process of inquiry. It did not convey the tentativeness of scientific knowledge and show how such intellectual skills as the ability to reason inductively and deductively, to classify objects and phenomena, to predict, to hypothesize, etc. contribute to the development of scientific concepts. It also, failed to provide basic understandings of the limitations and assumptions of science as a way of interpreting nature. Finally, science instruction was not effectively communicating the interrelationships among science, technology, and society.

In an attempt to upgrade the nation's science education programs, the Federal government invested large sums of money in curriculum development projects and in programs designed to upgrade and/or retrain teachers, especially during the 1960's and early 70's. Thus, BSCS biology, AAAS elementary science, AYI's and summer institutes came into being.

A chief aim of most of the Federally-sponsored projects and programs was to directly or indirectly improve science education by making it reflect the true "nature of science." The impact of these projects and programs has catalyzed production of a large body of literature on the so-called "nature of science." Much of what has been written is not of an empirical nature and will not be reviewed today.

PURPOSE

The purpose of this paper is: (1) to review empirical studies pertaining to teaching and learning the nature of science; (2) to attempt to synthesize a single set of conclusions based on the findings of studies reviewed; and (3) to attempt to suggest possible lines of new research.

DEFINING AND MEASURING "THE NATURE OF SCIENCE"

Before describing the results of my study, perhaps it would be helpful to give a definition of the "nature of science" and to indicate how an understanding of it is measured.

It will probably come as no surprise to you to learn that there is no conventional or otherwise agreed upon definition of the nature of science. However, Durkee and Cossman, in a study presented at the 1976 meeting of NARST, reported a high degree of agreement among scientists relative to their perceptions of the nature of science.

Doran, et. al. (1974) have attempted to decipher the various usages of the term and to synthesize a comprehensive definition. Their definition, and the one I shall use for lack of a better one, states that the

nature of science includes:

1. The methods and aims of science
2. The characteristics of scientists
3. The assumptions of science
4. The processes of science
5. The interactions of science with technology and society

Measurement of understanding, relative to the nature of science, has thus far been determined primarily through objective, paper and pencil type tests. The two most widely used instruments are the Test on Understanding Science Form W (TOUS) and the Wisconsin Inventory of Scientific Processes (WISP). Doran, et. al. (1974) have reviewed and compared the available instruments. A sample from the WISP is given in Appendix A.

RESULTS

Fourteen empirical studies pertaining to teaching and learning the nature of science were identified. Studies were classified into four categories. The categories were:

1. Descriptive Studies — Studies which describe or measure understanding of science in one or more groups of subjects.
2. Correlational Studies — Studies which attempt to correlate one or more factors with understanding of science.
3. Evaluational Studies — Studies designed to evaluate the effects of a course or project on participants understanding of science.
4. Multi-purpose Studies — Studies which combine two or more of the above categories.

Each study was analyzed and a brief "digest" prepared. A presentation of these "digests" follows:

DS

AUTHOR/SOURCE: MILLER, PHILIP E. (1963) PROCEEDINGS OF THE IOWA ACADEMY OF SCIENCE 70: 510-513.

SUBJECTS: AVERAGE-ABILITY STUDENTSIN GRADES 7 THROUGH 10; HIGH-ABILITY STUDENTS IN GRADES 11 AND 12; AND BIOLOGY TEACHERS. Ss WERE SELECTED AT RANDOM FROM EIGHT DIFFERENT SCHOOLS IN IOWA.

PROBLEM: TO DETERMINE HOW WELL BIOLOGY TEACHERS AND SELECTED GROUPS OF STUDENTS UNDERSTAND SCIENCE.

INSTRUMENT: TEST ON UNDERSTANDING SCIENCE (TOUS)

FINDINGS:

GROUP	N	MEAN (60 MAX.)
7TH GRADERS	205	23.61
8TH GRADERS	328	24.51
9TH GRADERS	52	31.13
10TH GRADERS	63	29.10
11TH AND 12TH GR. (HI-AB.)	87	42.11
BIOLOGY TEACHERS	51	43.59

NOTE: CRITICAL MEAN DIFFERENCE FOR SIGNIFICANCE AT THE .01 LEVEL WAS $\pm$ 2.62.

DS

AUTHOR/SOURCE: SCHMIDT, DONALD J. (1968) JOURNAL OF RESEARCH IN SCIENCE TEACHING 5(4): 365-366.

SUBJECTS: STUDENTS (GRADES 7-12), SCIENCE TEACHERS, AND SCIENTISTS FROM IOWA.

PROBLEM: (1) TO REPLICATE MILLER'S (1963) STUDY, AND

(2) TO COMPARE: (A) SECONDARY SCIENCE METHODS STUDENTS (COLLEGE SENIORS; N=29), (B) ELEMENTARY SCIENCE SURVEY STUDENTS (COLLEGE SOPHOMORES; N=43), AND WORKING SCIENTISTS (N=116) FROM UNIVERSITIES AND INDUSTRY WITH REGARD TO THEIR UNDERSTANDING OF SCIENCE.

INSTRUMENT: TEST ON UNDERSTANDING SCIENCE (TOUS)

FINDINGS: A GENERAL INCREASE IN UNDERSTANDING OF SCIENCE WITH INCREASED AGE AND MATURITY WAS FOUND. GENERALLY, MILLER'S FINDINGS WERE CONFIRMED. ALTHOUGH TEACHERS SCORED HIGHER THAN 11TH AND 12TH GRADERS, 25% OF THE TEACHERS WERE OUTSCORED BY 47% OF THESE HIGH ABILITY JUNIORS AND SENIORS.

GROUP	MEAN (MAX.=60)
7TH GRADERS	24.9
9TH GRADERS	34.0
11TH AND 12TH GRADERS (HI-AB.)	41.0
SCIENCE TEACHERS	45.5
SCIENCE METHODS STUDENTS (COLLEGE SENIORS)	48.0
ELEMENTARY SCIENCE SURVEY STUDENTS (COLLEGE SOPHOMORES)	40.5
WORKING SCIENTISTS	50.8

AUTHOR/SOURCE: KIMBALL, MERRITT E. (1968) JOURNAL OF RESEARCH IN SCIENCE TEACHING 5(2): 110-120.

SUBJECTS: STUDENTS AND GRADUATES OF SAN JOSE STATE AND STANFORD UNIVERSITIES IN CALIFORNIA (N=712).

PROBLEM: (1) TO COMPARE THE FOLLOWING GROUPS WITH RESPECT TO THEIR KNOWLEDGE OF SCIENCE:

(A) QUALIFIED SCIENCE TEACHERS VS. WORKING SCIENTISTS, AND

(B) SCIENCE MAJORS (TEACHERS & SCIENTISTS) VS. PHILOSOPHY MAJORS.

(2) TO DETERMINE IF KNOWLEDGE OF THE SCIENCE REMAINS STABLE WITH TIME.

INSTRUMENT: NATURE OF SCIENCE SCALE (NOSS)

FINDINGS: (1) QUALIFIED SCIENCE TEACHERS AND WORKING SCIENTISTS SHOWED NO SIGNIFICANT DIFFERENCE IN THEIR UNDERSTANDING OF SCIENCE.

(2) OVER THE TWELVE-YEAR TIME SPAN STUDIED, KNOWLEDGE OF SCIENCE APPEARED TO REMAIN STABLE IN BOTH WORKING SCIENTISTS AND TEACHERS.

(3) PHILOSOPHY MAJORS HAD SIGNIFICANTLY HIGHER NOSS SCORES THAN SCIENCE MAJORS, ESPECIALLY ON THE METHODOLOGY OF SCIENCE SUBSCALE.

DS

AUTHOR/SOURCE: JERKINS, KENNETH F. (1967) PAPER PRESENTED AT THE FORTIETH ANNUAL MEETING OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING (CHICAGO, ILLINOIS).

SUBJECTS: FOUR CATEGORIES OF STUDENTS ENROLLED AT THREE INSTITUTIONS OF HIGHER EDUCATION:

(1) FRESHMEN AND SOPHOMORES ENROLLED IN SCIENCE COURSES FOR NON-SCIENCE MAJORS,

(2) UPPERCLASSMEN ENROLLED IN SPECIAL METHODS COURSES FOR SECONDARY-LEVEL SCIENCE TEACHERS,

(3) ELEMENTARY TEACHERS ENROLLED IN GRADUATE SCIENCE EDUCATION COURSES, AND

(4) SECONDARY SCIENCE TEACHERS ENROLLED IN GRADUATE SCIENCE EDUCATION COURSES.

PROBLEM: TO COMPARE FOUR ACADEMIC GROUPS (LISTED ABOVE) WITH REGARD TO THEIR UNDERSTANDING OF SCIENCE.

INSTRUMENT: TEST ON UNDERSTANDING SCIENCE (TOUS)

FINDINGS: THERE WERE NO SIGNIFICANT DIFFERENCES BETWEEN THE ACADEMIC GROUPS WITHIN INSTITUTION. HOWEVER, THERE WERE SOME BETWEEN INSTITUTION DIFFERENCES.

AUTHOR/SOURCE: AYERS, JERRY B. (1976) J. TENN. ACAD. SCI. 51(1): 14-15.

PROBLEM: TO MEASURE ELEMENTARY TEACHERS' UNDERSTANDING OF SCIENCE AND ITS METHODS

SUBJECTS: ELEMENTARY TEACHERS AND PROSPECTIVE ELEMENTARY TEACHERS ENROLLED IN ELEMENTARY METHODS AT TENNESSEE TECH. (1973-75); 12-64 HRS IN SCIENCE, $\bar{x}$=20 (N=161)

INSTRUMENT: PROCESSES OF SCIENCE TEST (POST) - (ADMINISTERED AT MID-TERM)

FINDINGS: POST $\bar{x}$=29.0 (COMPARED TO 26.1 FOR HIGH SCHOOL STUDENTS IN BSCS)

POST SCORE/GRADUATE GPA CORRELATION WAS 0.64 ($p < .01$)

POST SCORE/METHOD COURSE GRADE CORRELATION WAS 0.52 ($p < .01$)

10

CS

AUTHOR/SOURCE: CAREY, RUSSELL L. AND NYLES G. STAUSS (1969)
BULLETIN OF THE GEORGIA ACADEMY OF SCIENCE
27(3): 148-158.

SUBJECTS: PROSPECTIVE SECONDARY SCIENCE TEACHERS (N=35) AND PROSPECTIVE ELEMENTARY TEACHERS (N=221) ENROLLED AT THE UNIVERSITY OF GEORGIA.

PROBLEM: TO DETERMINE WHAT RELATIONSHIP EXISTED BETWEEN PROSPECTIVE SCIENCE TEACHER'S UNDERSTANDING OF SCIENCE AND CERTAIN ACADEMIC VARIABLES.

ACADEMIC VARIABLES: NUMBER OF ACADEMIC UNITS IN: HIGH SCHOOL SCIENCE, AND COLLEGE-LEVEL MATHEMATICS, PHYSICAL SCIENCE, BIOLOGICAL SCIENCE, AND SCIENCE (TOTAL).

GRADE POINT AVERAGE IN: COLLEGE-LEVEL MATHEMATICS PHYSICAL SCIENCE, BIOLOGICAL SCIENCE, SCIENCE (TOTAL), AND COLLEGE (ALL SUBJECTS).

INSTRUMENT: WISCONSIN INVENTORY OF SCIENTIFIC PROCESSES (WISP)

FINDINGS:

(1) PROSPECTIVE SECONDARY TEACHERS OBTAINED SIGNIFICANTLY HIGHER WISP SCORES THAN DID PROSPECTIVE ELEMENTARY TEACHERS ($\bar{x}$=68.00 VS. $\bar{x}$=59.84).

(2) CORRELATION COEFFICIENTS BETWEEN WISP SCORE AND THE ACADEMIC VARIABLES STUDIED WERE GENERALLY POSITIVE FOR BOTH THE PROSPECTIVE ELEMENTARY TEACHERS AND SECONDARY TEACHERS, BUT NONE WERE STATISTICALLY SIGNIFICANT AT THE .05 LEVEL.

ES

AUTHOR/SOURCE: CRUMB, GLENN H. AND GERALD L. ABEGG (1967) PAPER PRESENTED AT THE FORTIETH ANNUAL MEETING OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING (CHICAGO, ILLINOIS).

SUBJECTS: COLLEGE STUDENTS ENROLLED IN A GENERAL EDUCATION PHYSICAL SCIENCE COURSE.

PROBLEM: TO EVALUATE STUDENT GAINS IN UNDERSTANDING SCIENCE IN TERMS OF HIGH SCHOOL SCIENCE BACKGROUND (I.E. Ss <u>WITH</u> HIGH SCHOOL CHEMISTRY AND PHYSICS VS. Ss <u>WITHOUT</u> HIGH SCHOOL CHEMISTRY AND PHYSICS).

INSTRUMENT: TEST ON UNDERSTANDING SCIENCE (TOUS)

FINDINGS: Ss WHO HAD NOT HAD HIGH SCHOOL CHEMISTRY AND PHYSICS SHOWED STATISTICALLY SIGNIFICANT GAINS (0.01 LEVEL) IN UNDERSTANDING THE NATURE OF SCIENCE WHILE Ss WHO HAD HAD HIGH SCHOOL CHEMISTRY AND PHYSICS FAILED TO SHOW A SIGNIFICANT GAIN AT THE .05 LEVEL OF SIGNIFICANCE.

AUTHOR/SOURCE: WELCH, WAYNE W. AND HERBERT J. WALBERG (1968) JOURNAL OF RESEARCH IN SCIENCE TEACHING 5(2): 105-109.

PROBLEM: TO EVALUATE SELECTED SUMMER INSTITUTES FOR PHYSICS TEACHERS (HPP) IN TERMS OF THEIR EFFECT ON TEACHER UNDERSTANDING OF SCIENCE.

SUBJECTS: EXPERIENCED PHYSICS TEACHERS ENROLLED IN FOUR DIFFERENT INSTITUTES (RANGE OF N=30-49; TOTAL N=153).

INSTRUMENT: TEST ON UNDERSTANDING SCIENCE (TOUS)

		PRETEST		POSTTEST		
INSTITUTE	N	$\bar{X}$	S	$\bar{X}$	S	MEAN GAIN
A	35	48.80	5.40	50.37	3.43	+1.57*
B	49	44.25	9.36	47.47	5.97	+3.22*
C	33	43.97	6.34	44.24	7.10	+0.27
D	30	38.37	8.61	40.97	7.03	+2.60*

*$p < .05$

AUTHOR/SOURCE: LAVACH, JOHN F., (1969) JOURNAL OF RESEARCH IN SCIENCE TEACHING 6(2): 166-170.

PROBLEM: TO EVALUATE AN IN-SERVICE PROGRAM IN THE HISTORICAL DEVELOPMENT OF SELECTED PHYSICAL SCIENCE CONCEPTS IN TERMS OF ITS EFFECT ON SCIENCE TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE.

SUBJECTS: SCIENCE TEACHERS FROM THE DURHAM, NORTH CAROLINA AREA (N=26).

INSTRUMENT: TEST ON UNDERSTANDING SCIENCE (TOUS)

FINDINGS:

		EXP. GROUP (N=11)		REF GROUP (N=15)
		PRETEST	POSTTEST	
(TOUS)	$\bar{X}$	35.27	38.91*	30.06

*SIGNIFICANTLY GREATER THAN EITHER THE PRETEST $\bar{X}$ OR REFERENCE GROUP $\bar{X}$ AT THE .01 LEVEL USING FISHER'S T-TEST FOR SMALL SAMPLES.

MPS

AUTHOR/SOURCE: CAREY, RUSSELL L. AND NYLES G. STAUSS (1968) SCIENCE EDUCATION 52(4): 358-363.

PROBLEM: TO DETERMINE:

(1) PROSPECTIVE SECONDARY SCIENCE TEACHER'S CONCEPT OF SCIENCE,

(2) WHAT RELATIONSHIP EXISTS BETWEEN PROSPECTIVE SECONDARY SCIENCE TEACHER'S CONCEPT OF SCIENCE AND CERTAIN ACADEMIC VARIABLES, AND

(3) WHETHER A SCIENCE METHODS COURSE CAN MAKE A SIGNIFICANT CONTRIBUTION TO PROSPECTIVE SCIENCE TEACHER'S UNDERSTANDING OF SCIENCE.

SUBJECTS: STUDENTS ENROLLED IN THE SECONDARY SCIENCE METHODS COURSE AT THE UNIVERSITY OF GEORGIA (N=17).

INSTRUMENT: WISCONSIN INVENTORY OF SCIENTIFIC PROCESSES (WISP) AND AN ASSIGNED ESSAY ON, "WHAT IS YOUR CONCEPT OF THE NATURE OF SCIENCE?"

FINDINGS: RESULTS OF STUDENT ESSAYS:

(1) A MINORITY OF PROSPECTIVE SECONDARY SCIENCE TEACHERS CONSIDER SCIENCE TO BE A BODY OF KNOWLEDGE, AND A METHOD OF INQUIRY.

(2) A MAJORITY OF THE PROSPECTIVE SECONDARY TEACHERS RECOGNIZE SCIENCE AS A HUMAN ENDEAVOR.

(3) A MINORITY OF THE Ss CONSIDERED SCIENCE AND TECHNOLOGY SYNONOMOUS.

(4) SOME Ss CONSIDERED SCIENCE AND NATURE SYNONOMOUS.

(5) Ss WERE MORE LIKELY TO VIEW SCIENCE AS A HUMAN ENDEAVOR THAN A METHOD OF INQUIRY AND MORE LIKELY TO VIEW SCIENCE AS A METHOD OF INQUIRY THAN AS A BODY OF KNOWLEDGE.

RESULTS OF THE CORRELATIONAL STUDY OF WISP SCORES AND THE SELECTED ACADEMIC VARIABLES SHOWED NO SIGNIFICANT CORRELATIONS EXCEPT FOR WISP PRETEST SCORE AND BIOLOGICAL SCIENCE GPA (R=0.513). THE DIFFERENCE BETWEEN THE WISP PRETEST MEAN ($\bar{x}$=68.2) AND POSTTEST MEAN ($\bar{x}$=72.4) WAS SIGNIFICANT AT THE .01 LEVEL AND THUS INDICATED THAT A SECONDARY SCIENCE METHODS COURSE COULD CONTRIBUTE TOWARD GAINS IN UNDERSTANDING THE NATURE OF SCIENCE.

AUTHOR/SOURCE: OLSTAD, ROGER G. (1969) SCIENCE EDUCATION 53(1): 9-11.

PROBLEM: (1) TO DETERMINE THE RELATIONSHIP OF SCIENCE BACKGROUND INFORMATION TO STUDENT UNDERSTANDING OF THE NATURE OF SCIENCE.

(2) TO EVALUATE A COURSE IN ELEMENTARY SCHOOL SCIENCE IN TERMS OF ITS EFFECTIVENESS IN PROMOTING UNDERSTANDING OF THE NATURE OF SCIENCE.

SUBJECTS: PROSPECTIVE ELEMENTARY TEACHERS ENROLLED AT THE UNIVERSITY OF WASHINGTON (N=115).

INSTRUMENTS: ADVANCED GENERAL SCIENCE TEST (AGS) AND THE TEST ON UNDERSTANDING SCIENCE FORM W (TOUS).

FINDINGS: (1) SCIENCE SUBJECT MATTER KNOWLEDGE WAS RELATED TO UNDERSTANDING OF THE NATURE OF SCIENCE (AGS - TOUS CORRELATIONS RANGED FROM .50 TO .65)

(2) SIGNIFICANT GAINS IN UNDERSTANDING THE NATURE OF SCIENCE WERE MADE BY SUBJECTS ENROLLED IN THE COURSE IN ELEMENTARY SCHOOL SCIENCE.

AUTHOR/SOURCE: CAREY, RUSSELL L. AND NYLES G. STAUSS (1970)
SCHOOL SCIENCE AND MATHEMATICS 70(5): 366-376.

PROBLEM: TO DETERMINE:

(1) WHAT RELATIONSHIP EXISTS BETWEEN THE EXPERIENCED TEACHER'S UNDERSTANDING OF THE NATURE OF SCIENCE AND CERTAIN ACADEMIC VARIABLES,

(2) WHAT RELATIONSHIP EXISTS BETWEEN THE EXPERIENCED SCIENCE TEACHER'S UNDERSTANDING OF THE NATURE OF SCIENCE AND TEACHING EXPERIENCE,

(3) WHETHER A PROFESSIONAL SCIENCE EDUCATION COURSE CAN MAKE A SIGNIFICANT CONTRIBUTION TO THE EXPERIENCED SCIENCE TEACHER'S UNDERSTANDING OF THE NATURE OF SCIENCE.

SUBJECTS: SCIENCE TEACHERS ENROLLED IN AN ACADEMIC YEAR INSTITUTE AT THE UNIVERSITY OF GEORGIA (N=31).

INSTRUMENT: WISCONSIN INVENTORY OF SCIENTIFIC PROCESSES (WISP).

FINDINGS: (1) TOTAL COLLEGE SCIENCE HOURS AND COLLEGE BIOLOGICAL SCIENCE HOURS WERE SIGNIFICANTLY CORRELATED WITH WISP PRETEST SCORES AND COLLEGE BIOLOGICAL SCIENCE GPA WAS SIGNIFICANTLY CORRELATED WITH WISP POSTTEST SCORES. NONE OF THE OTHER ACADEMIC VARIABLES STUDIED SHOWED STATISTICALLY SIGNIFICANT CORRELATIONS WITH EITHER WISP PRETEST OR POSTTEST SCORES.

(2) NUMBER OF YEARS OF TEACHING EXPERIENCE WAS NOT SIGNIFICANTLY CORRELATED WITH EITHER WISP PRETEST OR POSSTEST SCORE.

(3) THE MEAN WISP SCORE FOR THE Ss AT THE BEGINNING OF THE PROFESSIONAL SCIENCE EDUCATION COURSE WAS 69.00 AND AT THE END OF THE COURSE WAS 78.61. THIS DIFFERENCE REPRESENTED A HIGHLY SIGNIFICANT GAIN AND INDICATED THAT A PROFESSIONAL SCIENCE EDUCATION COURSE COULD CONTRIBUTE TO TEACHER UNDERSTANDING OF THE NATURE OF SCIENCE.

AUTHOR/SOURCE: WOOD, ROGER L. (1972) SCHOOL SCIENCE AND MATHEMATICS 72(1): 73-79.

PROBLEM: TO DETERMINE:

(1) WHAT RELATIONSHIP EXISTS BETWEEN Ss UNDERSTANDING OF THE NATURE OF SCIENCE AND THE VARIABLES OF SEX, NUMBER OF UNIVERSITY SCIENCE CREDITS, NUMBER OF YEARS OF HIGH SCHOOL SCIENCE, AND AVERAGE GRADE IN SCIENCE AT THE UNIVERSITY LEVEL.

(2) IF A DIFFERENCE EXISTED BETWEEN PROSPECTIVE ELEMENTARY AND PROSPECTIVE SECONDARY TEACHERS' CONCEPT OF THE NATURE OF SCIENCE.

SUBJECTS: STUDENTS ENROLLED IN ELEMENTARY AND SECONDARY SCIENCE METHODS COURSES AT FIVE STATE UNIVERSITIES IN WISCONSIN. SAMPLE SIZE WAS N=365 FOR ELEMENTARY TEACHERS AND N=78 FOR SECONDARY TEACHERS.

INSTRUMENT: WISCONSIN INVENTORY OF SCIENTIFIC PROCESSES (WISP).

FINDINGS: MEAN WISP SCORES OBTAINED BY PROSPECTIVE SECONDARY TEACHERS WERE NOT SIGNIFICANTLY CORRELATED WITH ANY OF THE VARIABLES STUDIED EXCEPT AVERAGE SCIENCE COURSE GPA.

AUTHOR/SOURCE: LUCY, EDWARD C. (1974) PAPER PRESENTED AT THE FORTY-SEVENTH ANNUAL MEETING OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING (CHICAGO, ILLINOIS).

SUBJECTS: PROSPECTIVE SECONDARY SCIENCE TEACHERS (N=129) ENROLLED AT THE OHIO STATE UNIVERSITY.

PROBLEM: (1) TO DETERMINE WHETHER A LABORATORY SCIENCE PROGRAM COMPONENT (CONSISTING OF 39 INDIVIDUALIZED ACTIVITIES) OF A PROFESSIONAL SCIENCE EDUCATION COURSE WOULD CAUSE Ss TO SHOW SIGNIFICANT GAINS IN UNDERSTANDING THE NATURE OF SCIENCE.

(2) TO IDENTIFY VARIABLES WHICH WOULD ACCURATELY PREDICT GAINS IN UNDERSTANDING THE NATURE OF SCIENCE.

INSTRUMENT: WISCONSIN INVENTORY OF SCIENTIFIC PROVESSES (WISP)

FINDINGS: (1) SIGNIFICANT WISP GAINS INDICATED THAT THE LABORATORY SCIENCE PROGRAM WAS EFFECTIVE IN MAKING A CONTRIBUTION TO THE STUDENTS' UNDERSTANDING OF THE NATURE OF SCIENCE.

(2) TWO STATISTICALLY SIGNIFICANT PREDICTOR VARIABLES WERE IDENTIFIED, BUT IN THE ESTIMATION OF THE INVESTIGATOR WERE NOT EDUCATIONALLY SIGNIFICANT. THESE PREDICTORS WERE: (A) THE NUMBER OF HIGHER-ORDER PROCESSES OF SCIENCE ACTIVITIES COMPLETED AS A PART OF THE PROFESSIONAL EDUCATION COURSE, AND (B) THE Ss GPA IN HIS/HER MAJOR.

AUTHOR/SOURCE: BILLEH, VICTOR Y. AND OMAR E. HASAN (1975)
JOURNAL OF RESEARCH IN SCIENCE TEACHING 12(3): 209-219.

SUBJECTS: ALL SECONDARY SCIENCE TEACHERS IN JORDON (N=186).

PROBLEM: TO DETERMINE:

(1) WHETHER TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE CAN BE SIGNIFICANTLY INCREASED THROUGH A TRAINING COURSE IN SCIENCE TEACHING, AND

(2) WHETHER TEACHERS' GAIN IN UNDERSTANDING THE NATURE OF SCIENCE IS SIGNIFICANTLY CORRELATED WITH NUMBER OF YEARS OF COLLEGE EDUCATION IN SCIENCE, SCIENCE SUBJECT(S) TAUGHT, NUMBER OF YEARS OF SCIENCE TEACHING EXPERIENCE, AND TYPE OF PREVIOUS PROFESSIONAL TRAINING.

INSTRUMENT: NATURE OF SCIENCE TEST (NOST).

FINDINGS: (1) THE SCIENCE TRAINING COURSE RESULTED IN A SIGNIFICANT IMPROVEMENT IN THE Ss MEAN NOST SCORE (31.41 VS. 35.12; $P < 0.0001$).

(2) NOST GAIN SCORES WERE NOT SIGNIFICANTLY CORRELATED WITH ANY OF THE VARIABLES STUDIED.

AUTHOR/SOURCE: MATHIS, PHILIP M. AND PATRICK J. DOYLE (1976) UNPUBLISHED RESEARCH.

SUBJECTS: STUDENTS ENROLLED IN INTRODUCTORY GENETICS AT MIDDLE TENNESSEE STATE UNIVERSITY (N=35).

PROBLEM: (1) TO EVALUATE AN INQUIRY-ORIENTED GENETICS COURSE IN TERMS OF ITS EFFECTS ON STUDENT UNDERSTANDING OF SCIENCE.

(2) TO IDENTIFY FACTORS WHICH WERE SIGNIFICANT PREDICTORS OF STUDENT GAINS IN UNDERSTANDING SCIENCE.

INSTRUMENT: WISCONSIN INVENTORY OF SCIENTIFIC PROCESSES (WISP)

FINDINGS: (1) Ss WISP SCORES INCREASED SIGNIFICANTLY (.01 LEVEL) DURING THE GENETICS COURSE. WISP GAINS WERE NOT SIGNIFICANT, HOWEVER, FOR Ss WHICH WERE SIMULTANEOUSLY ENROLLED IN OTHER SCIENCE COURSES.

(2) THE FOLLOWING VARIABLES WERE SIGNIFICANT PREDICTORS (.01 LEVEL) OF WISP GAIN SCORES:

(1) GENDER (R=0.431)
(2) WISP PRETEST SCORE (R= -0.627), AND
(3) BIOLOGY CLASSROOM ACTIVITY CHECKLIST SCORE (R=0.453). THESE THREE VARIABLES GAVE A MULTIPLE R OF 0.7628, THUS ACCOUNTING FOR ABOUT 50% OF WISP SCORE GAIN VARIABILITY.
(4) THERE WAS A SIGNIFICANT CORRELATION (.01 LEVEL; R=.449) BETWEEN THE NUMBER OF COLLEGE-LEVEL SCIENCE COURSES COMPLETED AND WISP PRETEST SCORE.

CONCLUSIONS

Studies reviewed supported the following tentative, but general conclusions:

1. Prospective Secondary Science Teachers' Knowledge of the Nature of Science is Significantly Greater than that of Elementary Teachers, However, Both Prospective and Experienced Teachers of Science have an Inadequate Understanding of the Nature of Science. (Support for this conclusion comes from Miller, 1963; Jerkins, 1967; Carey and Stauss, 1968; Schmidt, 1968; Carey and Stauss, 1969; Olstad, 1969; Wood, 1972; Ayers, 1976)

2. Little, if any, Relationship Exists Between Science Teachers' Understanding of the Nature of Science and the Quality or Quantity of Their Academic Course Work in Science. (Support for this conclusion comes from Carey and Stauss, 1968; Carey and Stauss, 1969; Carey and Stauss, 1970; Wood, 1972; Lucy, 1974; Bulleh and Hasan, 1975)

3. No Relationship Exists Between Science Teachers' Understanding of the Nature of Science and Length of Teaching Experience. (Support for this conclusion comes from Kimball, 1968; Carey and Stauss, 1970; Billeh and Hasan, 1975)

4. Appropriately Designed Institutes, Science Courses, or Science Education Courses are Capable of Producing Significant Growth in Teacher and/or Student Understanding of the Nature of Science. (support for this conclusion comes from Carey and Stauss, 1968; Welch and Walberg, 1968; Lavach, 1969; Olstad, 1969; Carey and Stauss, 1970; Lucy, 1974; Billeh and Hasan, 1975; Mathis and Doyle, 1976)

5. Both Past and Concurrent Involvement in Science Courses Appear to Influence the Degree to Which Students and/or Teachers Profit from Experiences Designed to Improve Their Understanding of the Nature of Science. (Support for this conclusion comes from Crumb and Abegg, 1967; Welch and Walberg, 1968; Mathis and Doyle, 1976)

SUGGESTIONS FOR FUTURE RESEARCH

In attempting to review and synthesize the results of several pieces of research, the reviewer is often in a position to note critical deficiencies in the status of knowledge pertaining to a particular subject, and to suggest possible lines of study which might build up the defi-

cient areas. I would like to conclude my presentation by suggesting several possible studies which could help to provide a more complete picture of how the nature of science is taught and learned.

Suggestion One: More studies similar to the ones reviewed today need to be conducted. Unlike studies conducted thus far, however, they should involve large, randomly selected samples of subjects, thereby increasing the generalizability of the findings. Review papers, such as this, which attempt to summarize and synthesize the results of several small, independently conducted pieces of research are no substitute for large-scale studies.

Suggestion Two; Studies need to be conducted to determine how (and what) concepts, pertaining to the nature of science, are acquired in the elementary school years. (The current absence of studies dealing with young subjects is apparently attributable to the lack of appropriate instrumentation.

Suggestion Three: Studies need to be conducted which would determine the extent to which the nature of science is reflected in the actual classroom instruction of teachers who score high on instruments purporting to measure knowledge of the nature of science.

Suggestion Four: Studies need to be conducted which would determine what factors predispose science teachers to use teaching strategies which result in courses that accurately convey the nature of science.

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THE WISCONSIN INVENTORY OF SCIENCE PROCESSES

1. If a scientist repeatedly observes that condition *A* is followed by state *B*, then he can, by observing an instance of condition *A*, predict the occurrence of state *B*. — 1. A I D
2. Unpredicted observations have played a role in a majority of scientific achievements. — 2. A I D
3. The assumption made by scientists that space and time are real is defensible on the basis of past experience. — 3. A I D
4. Scientists look upon the existence of error in measurement as inevitable. — 4. A I D
5. One of the interests of the scientist is in finding relationships of the type, "When *A* occurs, then *B* will occur." — 5. A I D
6. Mathematical systems are used by scientists for organizing and communicating information about data. — 6. A I D
7. Classification schemes, such as the periodic table of the elements, are based on observed similarities and differences. — 7. A I D
8. A scientist prefers simple interpretations of phenomena. — 8. A I D
9. Scientists can, by following the scientific method step by step, answer almost any question concerning natural phenomena. — 9. A I D
10. Factual evidence produced by means of experimentation is the primary means of establishing the credibility of a scientific theory. — 10. A I D
11. A scientist formulates a working hypothesis after he has exhaustively examined the available facts and data. — 11. A I D
12. Science is a self-correcting enterprise. — 12. A I D
13. A scientist must have a definite idea of the kinds of observations he expects to make during an experiment. — 13. A I D
14. Prior to approaching a new problem, a scientist reviews the literature for relevant information. — 14. A I D
15. The scientist must be able to establish the credibility of the data he collects. — 15. A I D
16. Scientists use their present knowledge of events and phenomena as a means of explaining events and phenomena of the past. — 16. A I D
17. The scientist assumes a moral responsibility when he elects to do research in an area in which his findings could be destructive to society. — 17. A I D
18. Scientists attempt to keep the number of hypotheses and axioms utilized at a minimum. — 18. A I D
19. Scientists obtain and utilize data expressed in terms of statements of probability. — 19. A I D
20. A law in science is derived from a vast body of consistent experience. — 20. A I D
21. A basic objective of science is the generation of knowledge with technological application. — 21. A I D
22. A scientist publishes his research findings so that other members of the academic community may independently evaluate his work. — 22. A I D
23. A classification scheme is a useful method of organizing scientific observations. — 23. A I D
24. Scientists assume that all natural phenomena have natural causes. — 24. A I D
25. Scientific models are idealizations of reality. — 25. A I D
26. All contributions to the fund of scientific knowledge are public property, beyond the minimum credits for the achievement of discovery. — 26. A I D